Evidence & Explanation of a Sun-Hurricane Connection

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Acknowledgments: T. H. Jagger, Rob Hodges

Support: NSF, RPI, FCSRMC, Nephila

Take-Home Points

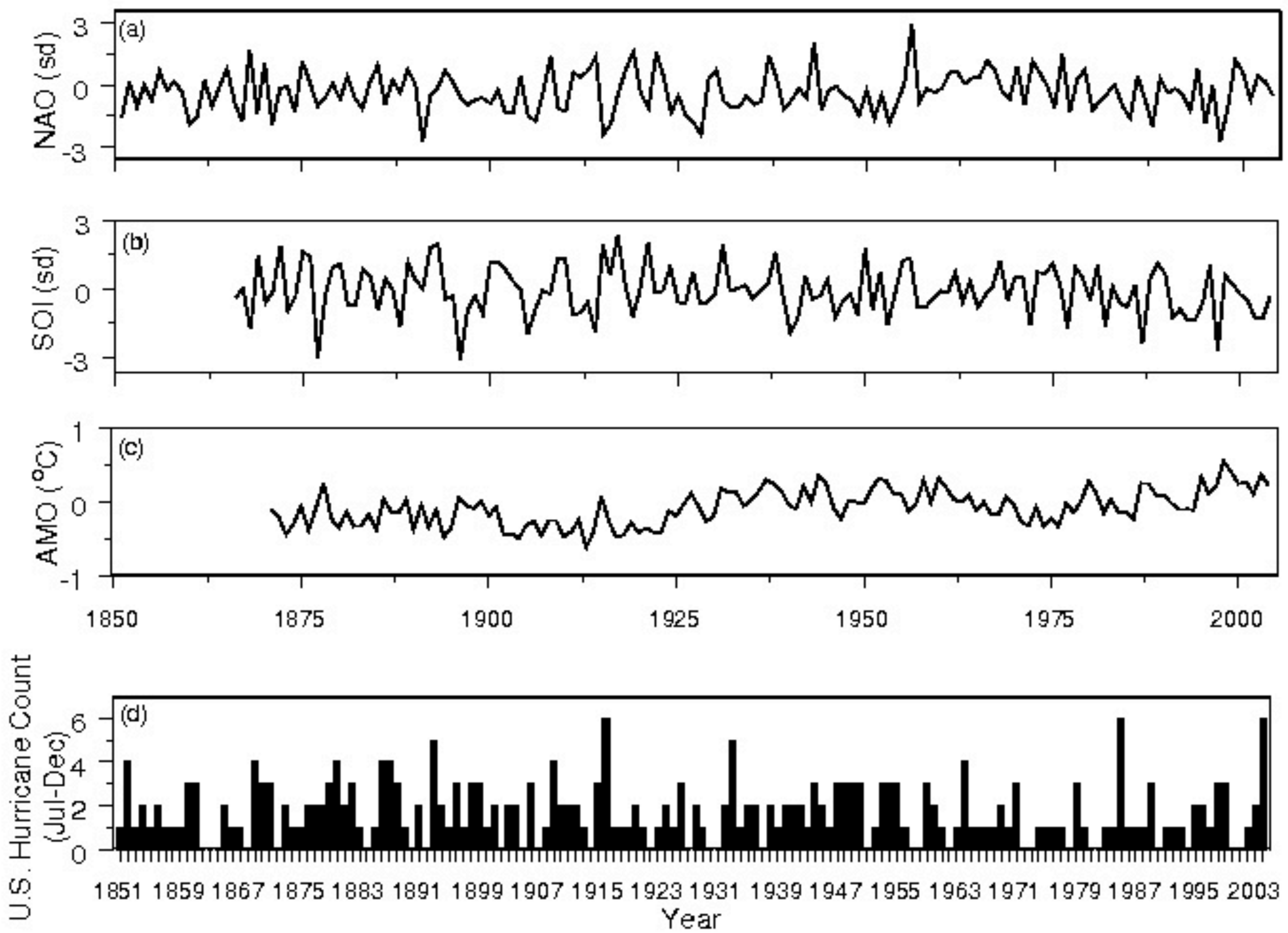
The probability of a U.S. hurricane from year to year fluctuates with sunspot numbers.

The relationship can be used to predict U.S. hurricanes and associated wind damage losses.

The relationship is likely the result of temperature variations above the hurricane.

The relationship is consistent with the heat-engine theory of tropical cyclone intensity.

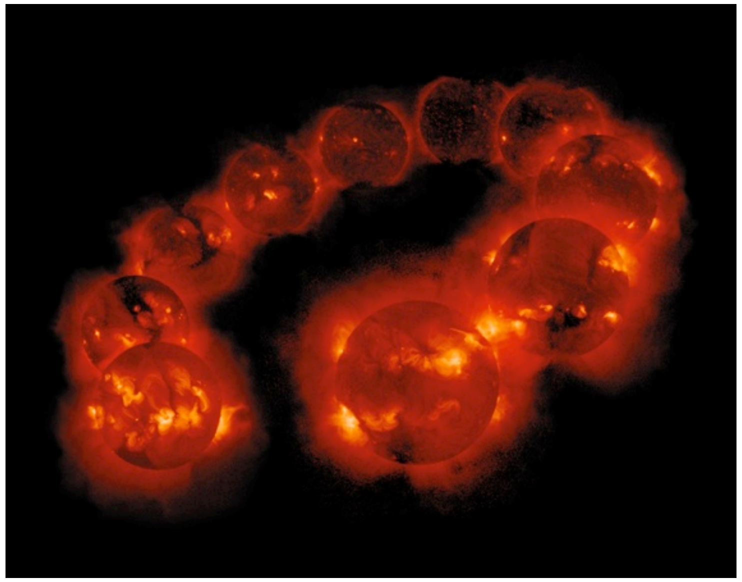
How did we discover the connection?



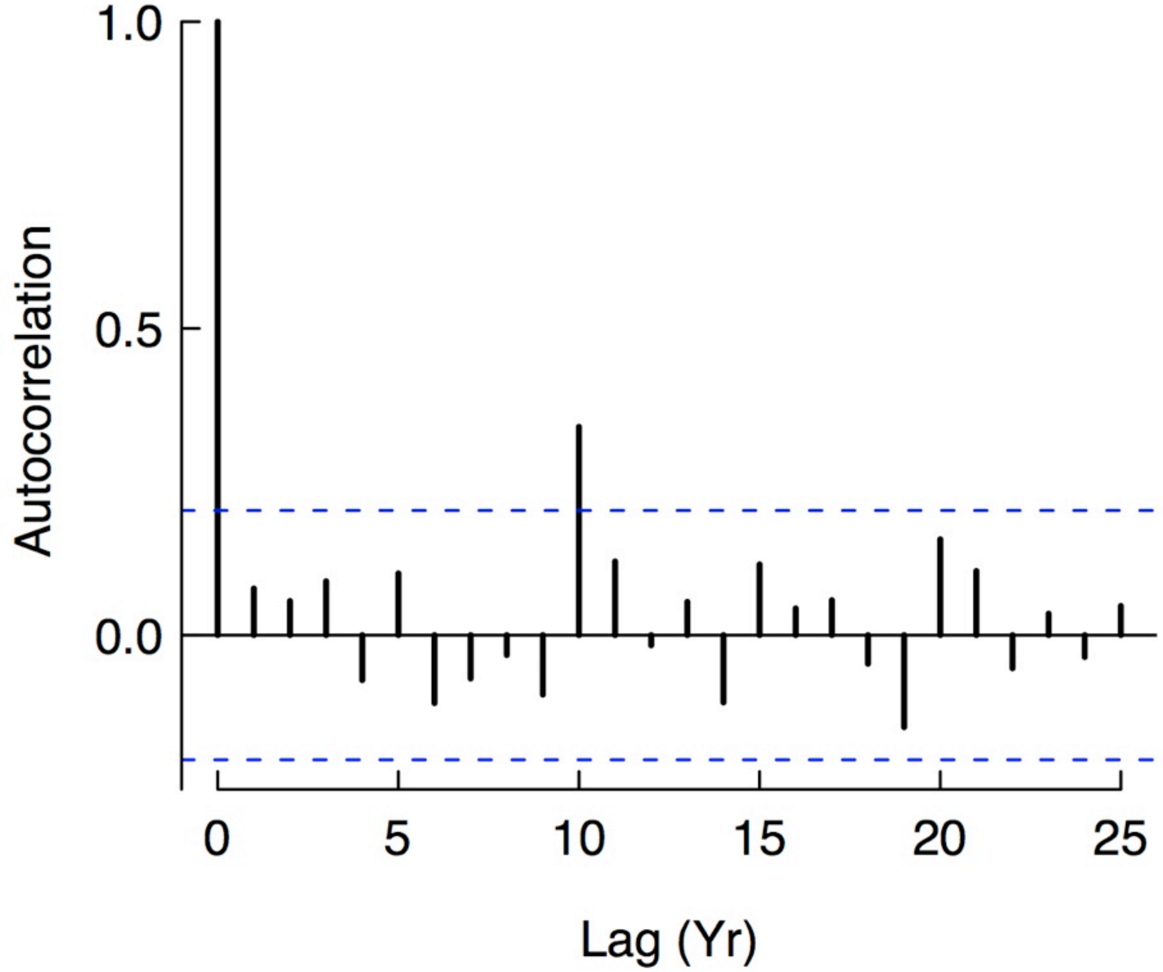
Term	Estimate	S.E.	z value	Pr(> z)
	TS + H 1900–2006			
NAO	−0.086	0.036	−2.694	0.007
SOI	+0.138	0.035	+3.899	<0.001
SST	+0.859	0.105	+8.191	<0.001
	TS + H 1914–2006			
NAO	−0.096	0.034	−2.839	0.005
SOI	+0.150	0.038	+3.931	<0.001
SST	+0.981	0.121	+8.110	<0.001
	TS + H 1944–2006			
NAO	−0.084	0.042	−2.000	0.046
SOI	+0.146	0.044	+3.291	0.001
SST	+0.817	0.148	+5.502	<0.001

Together the three covariates (SST, ENSO, & NAO) explain between 40 and 48% of the variation in tropical cyclone counts depending on start year.

But, what remains?



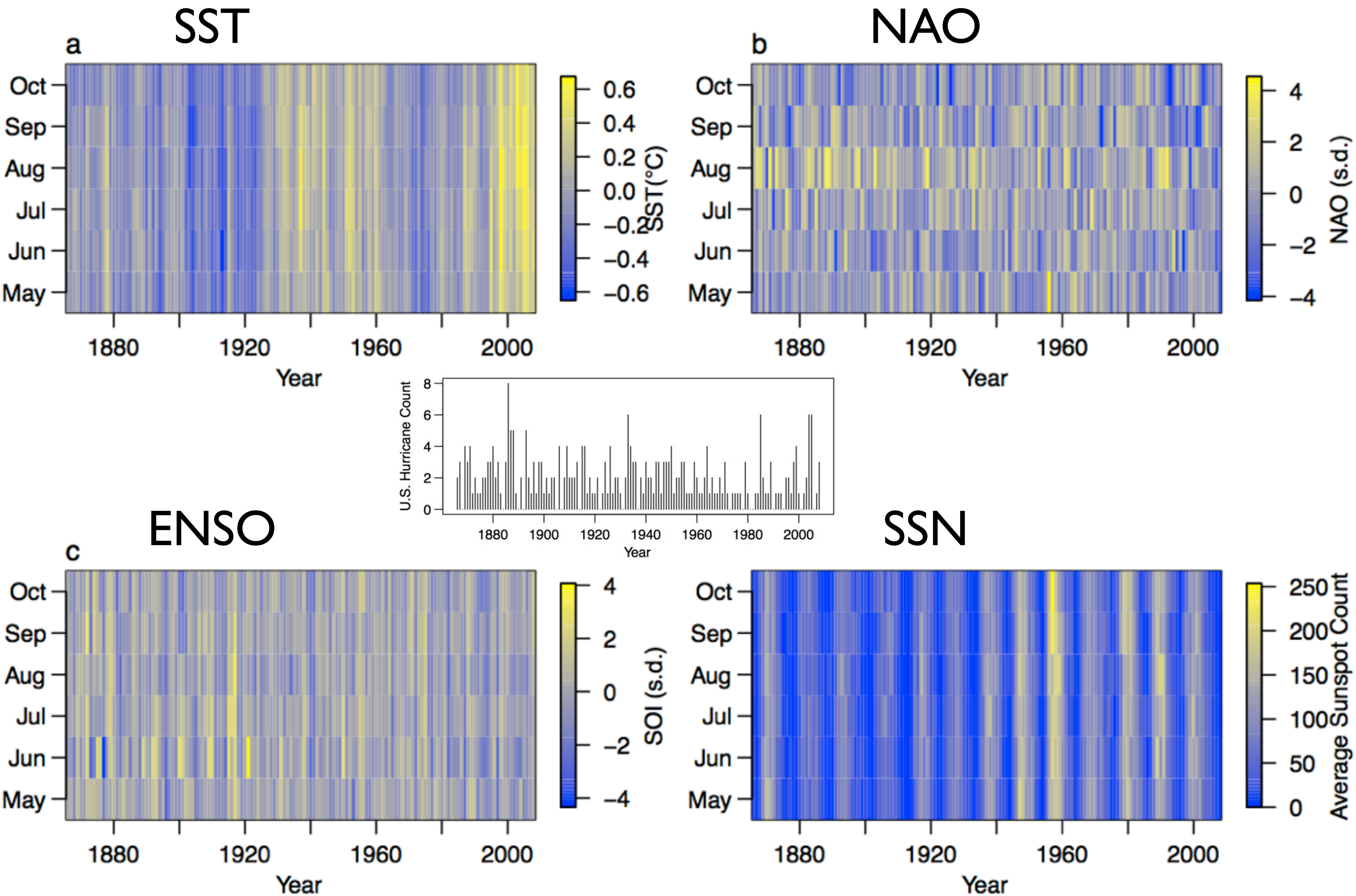
Courtesy: NOAA

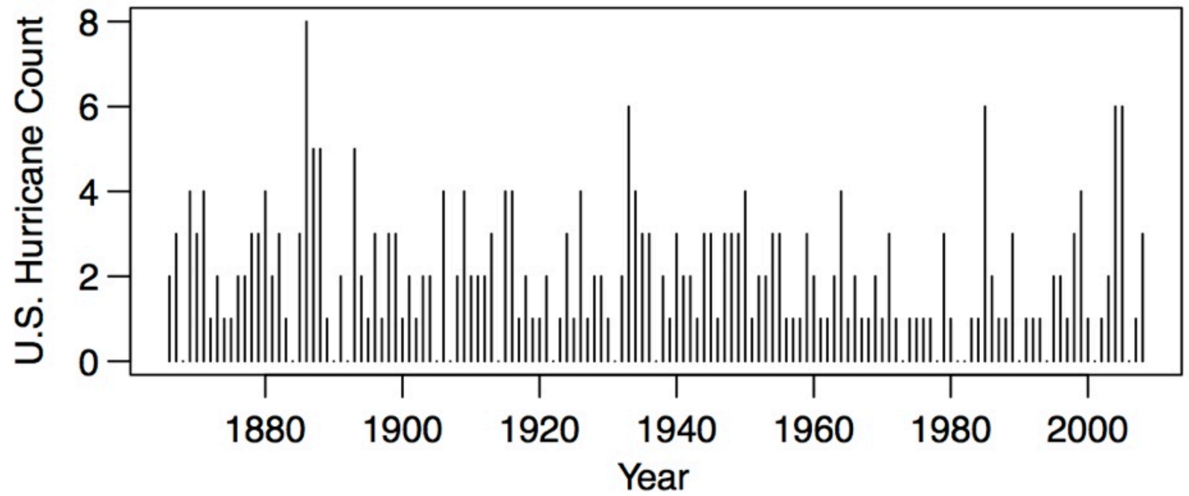


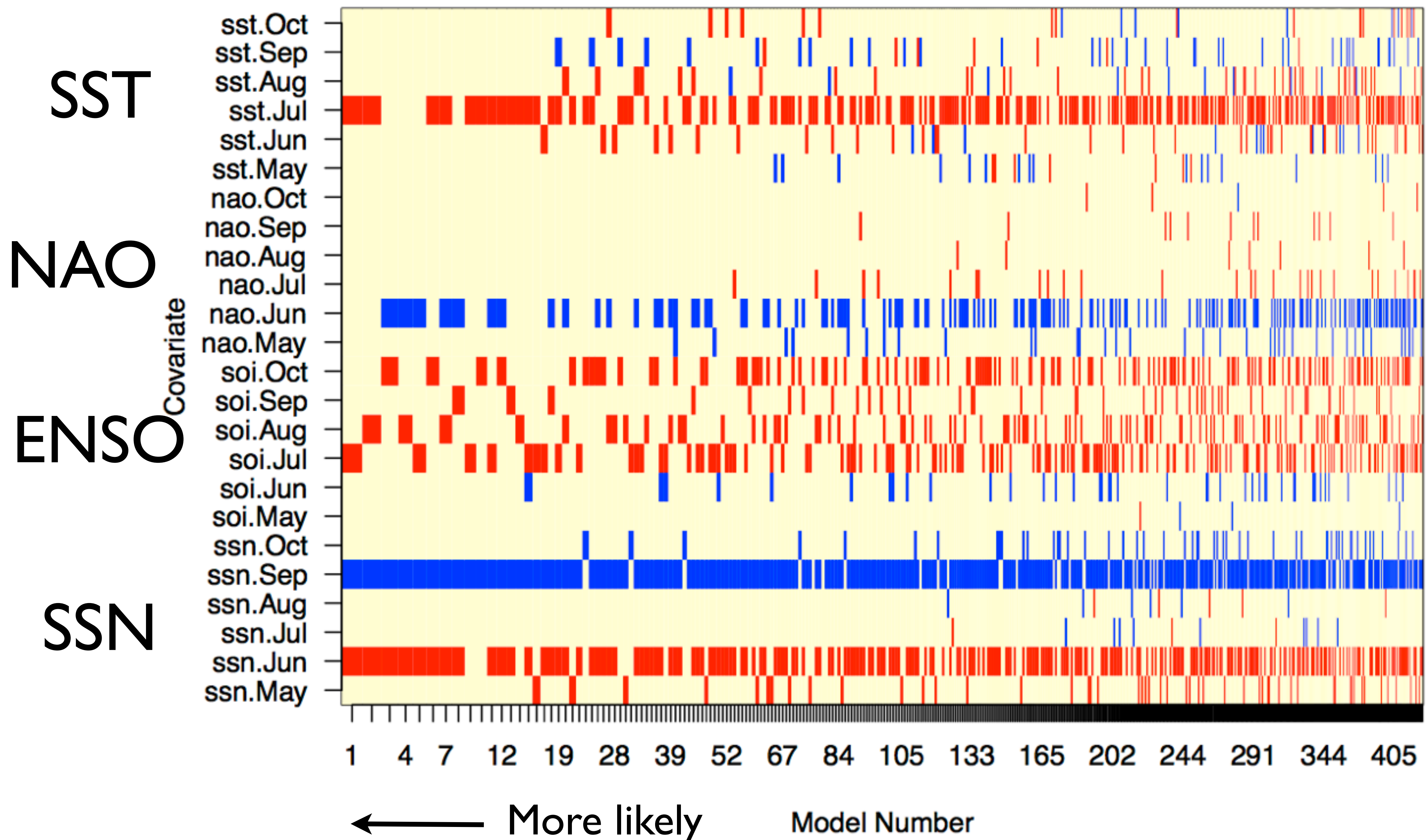
Autocorrelation function of the *residuals* from a Poisson regression model of U.S. hurricane counts on the SST, ENSO, & NAO.

	Coefficient			
Term	Estimate	S.E.	z value	Pr($>z$)
	US H 1866–2006			
NAO	−0.207	0.066	−3.143	0.002
SOI	+0.238	0.068	+3.514	<0.001
SST	+0.508	0.235	+2.164	0.030
SSN	−0.003	0.001	−1.979	0.048
	US H 1878–2006			
NAO	−0.202	0.069	−2.931	0.003
SOI	+0.272	0.071	+3.829	<0.001
SST	+0.499	0.236	+2.120	0.034
SSN	−0.003	0.002	−2.194	0.028
	US H 1900–2006			
NAO	−0.214	0.076	−2.820	0.005
SOI	+0.285	0.081	+3.487	<0.001
SST	+0.545	0.252	+2.161	0.031
SSN	−0.003	0.002	−1.992	0.046

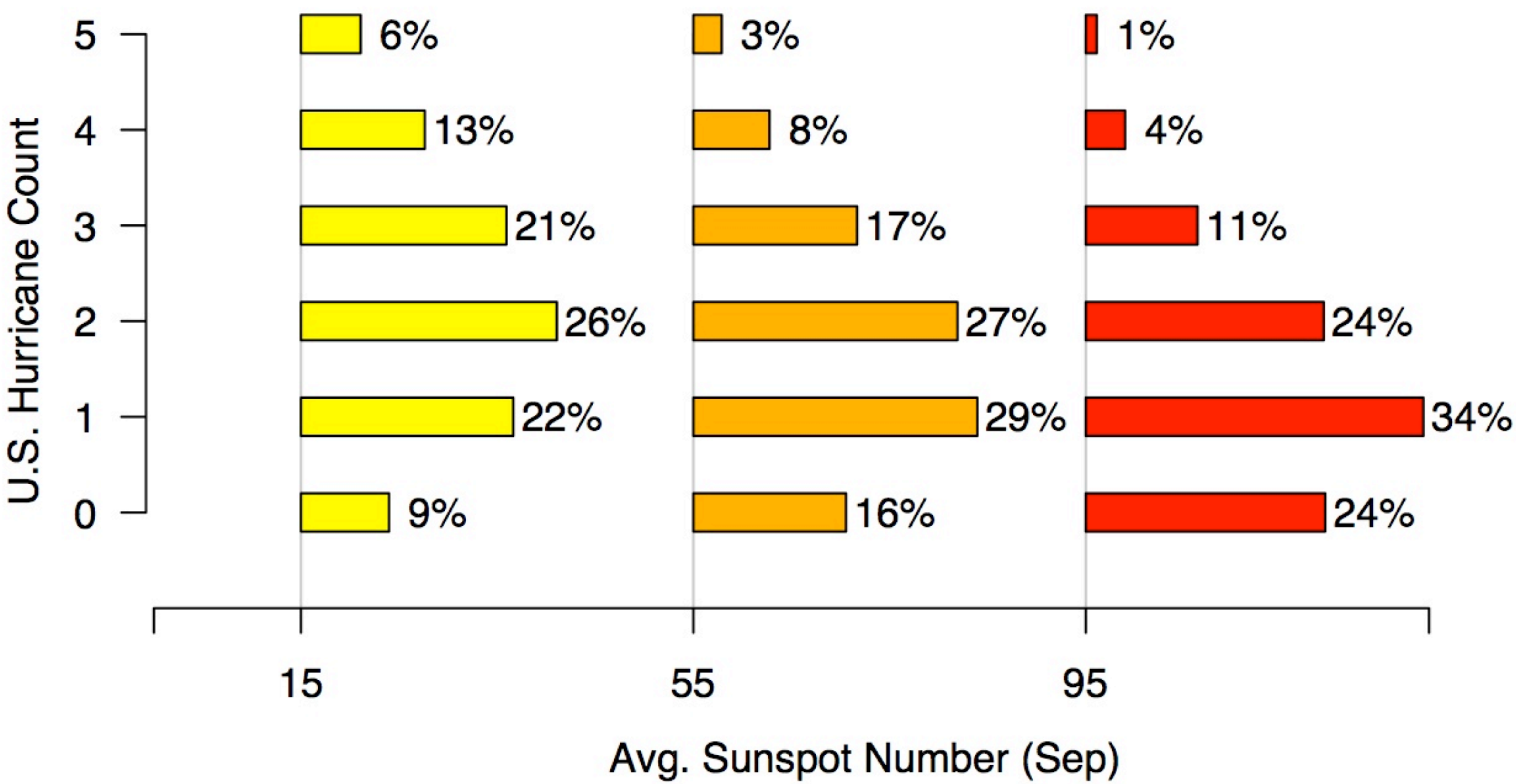
How important is it relative to other factors?





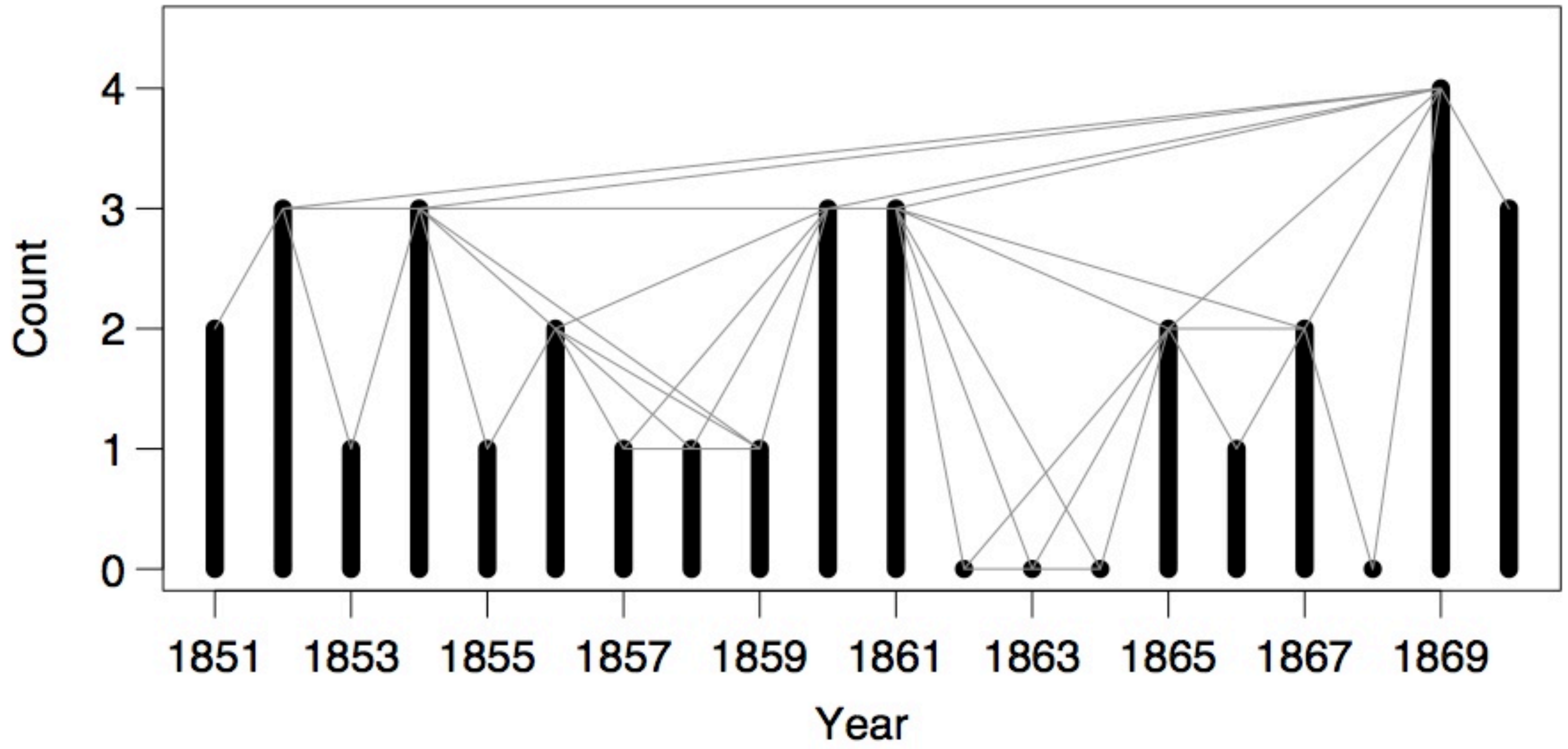


Jagger & Elsner, 2010

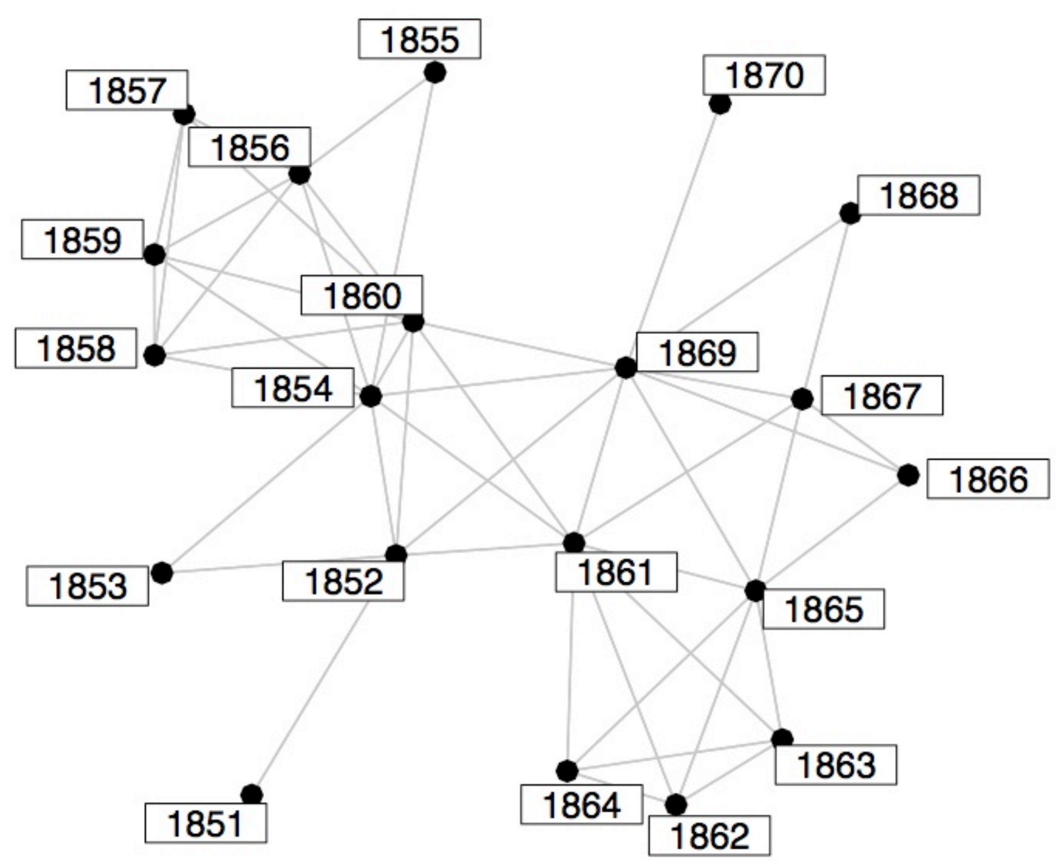


Probabilities of U.S. hurricanes during seasons with above normal ocean temperatures and conditional on sunspot numbers during September.

Solar activity better explains the unusual years



A visibility network of U.S. hurricanes emerges from time-series data after the work of Lacasa et al. (2008).



Visibility network of U.S. hurricanes 1851-2008

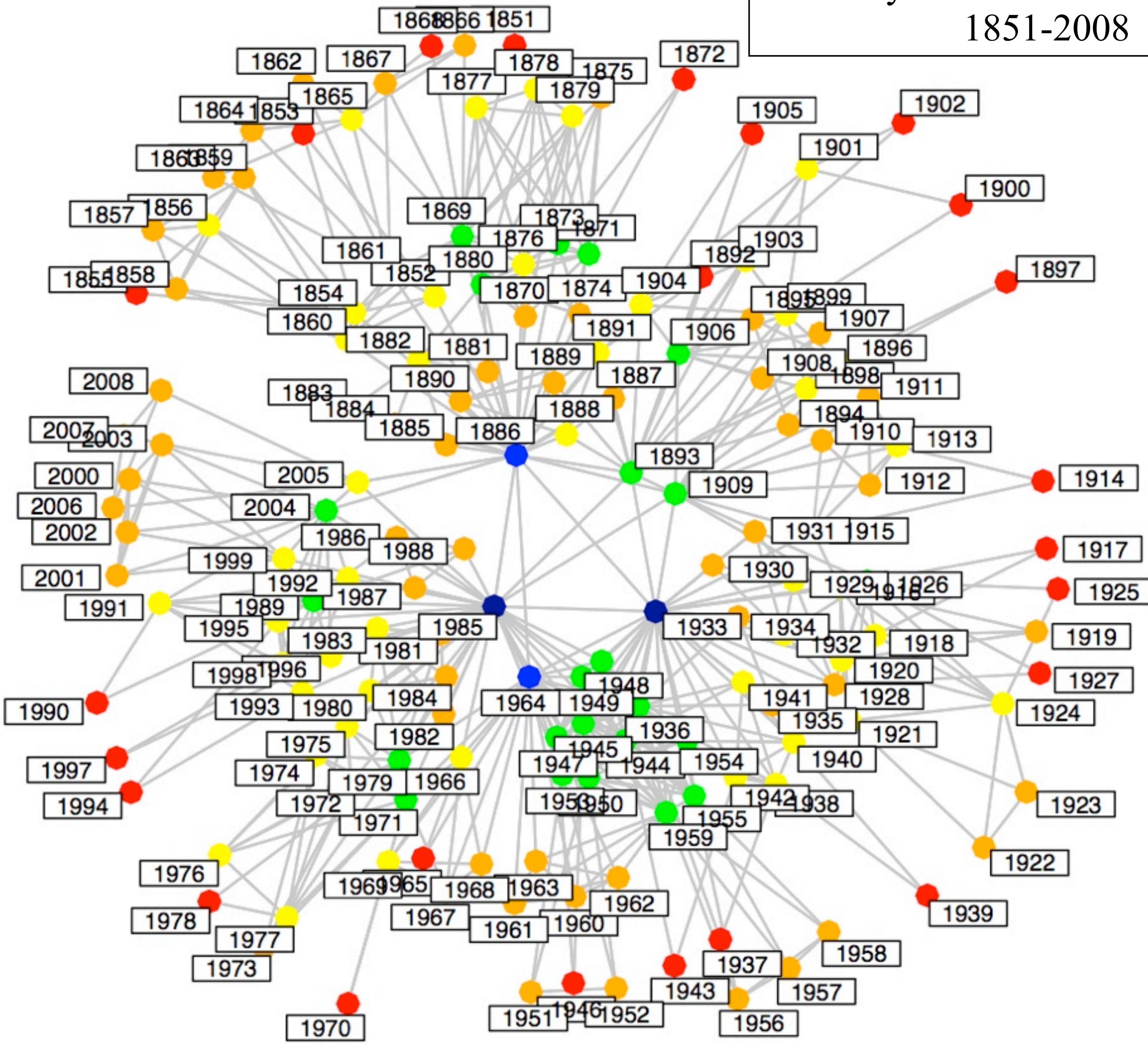
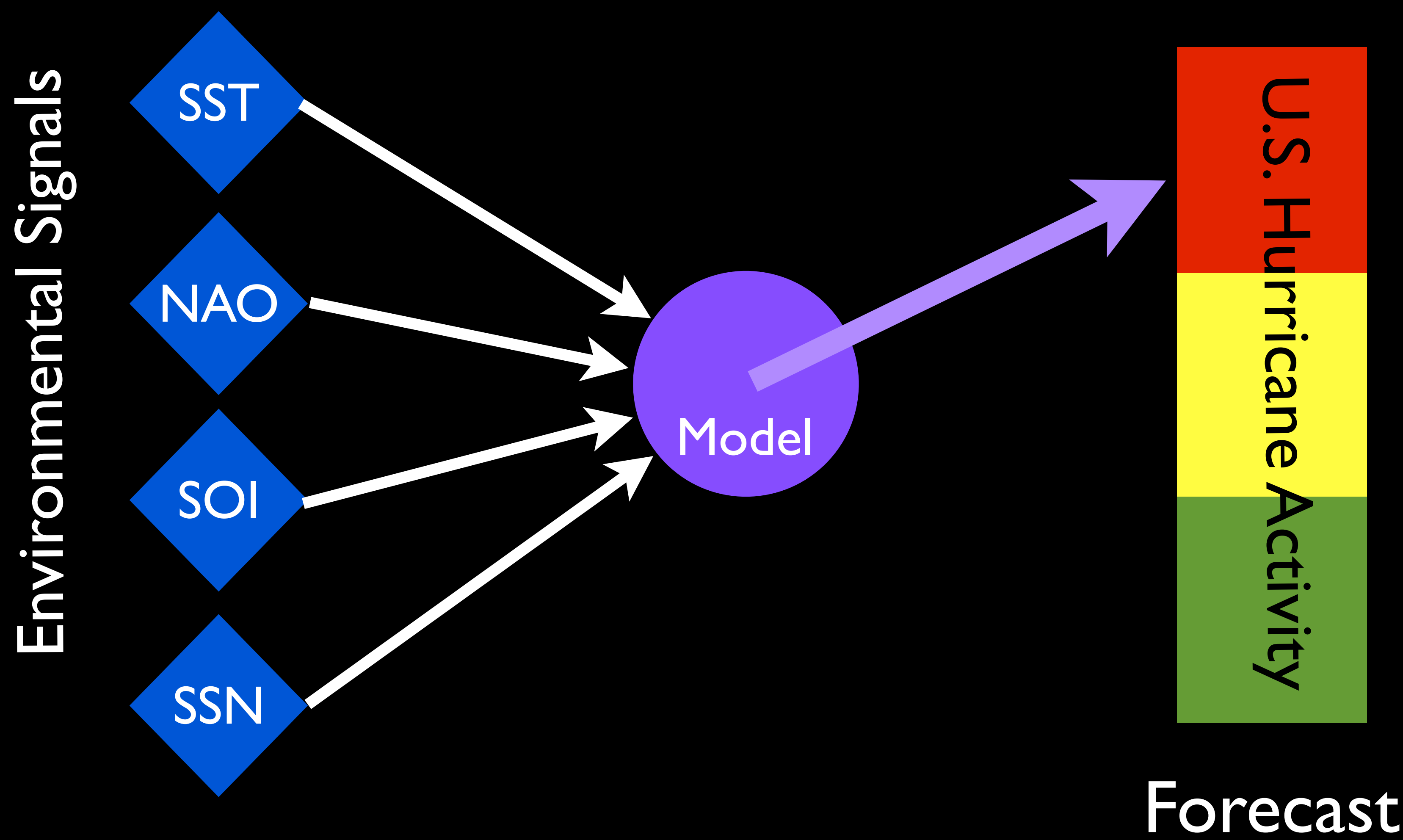
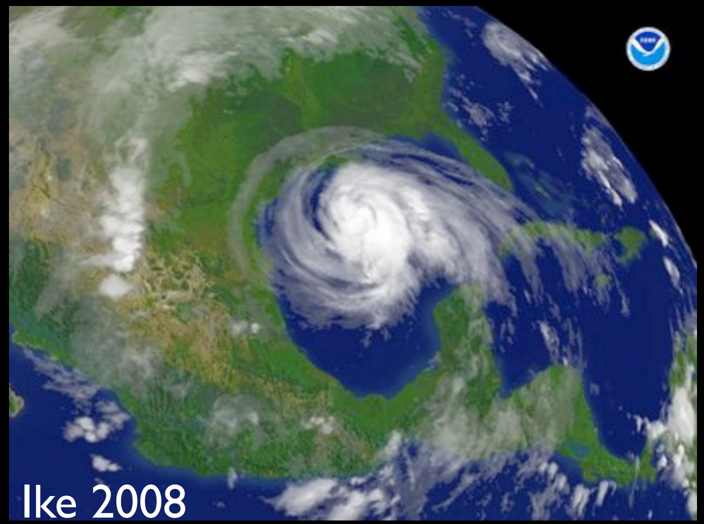


Table 1| Unusual hurricane years.

Rank	Degree	Year	Count	SST (Sep)	SOI (Sep)	NAO (Jun)	SSN (Sep)
1	36	1985	6	−0.41	+0.02	−0.54	−1.09
2	33	1933	5	+0.96	+0.19	−0.93	−1.07
3	30	1886	7	−0.50	+1.25	−0.62	−0.73
4	25	1964	4	−0.58	+1.26	−1.10	−1.07

How is it used?

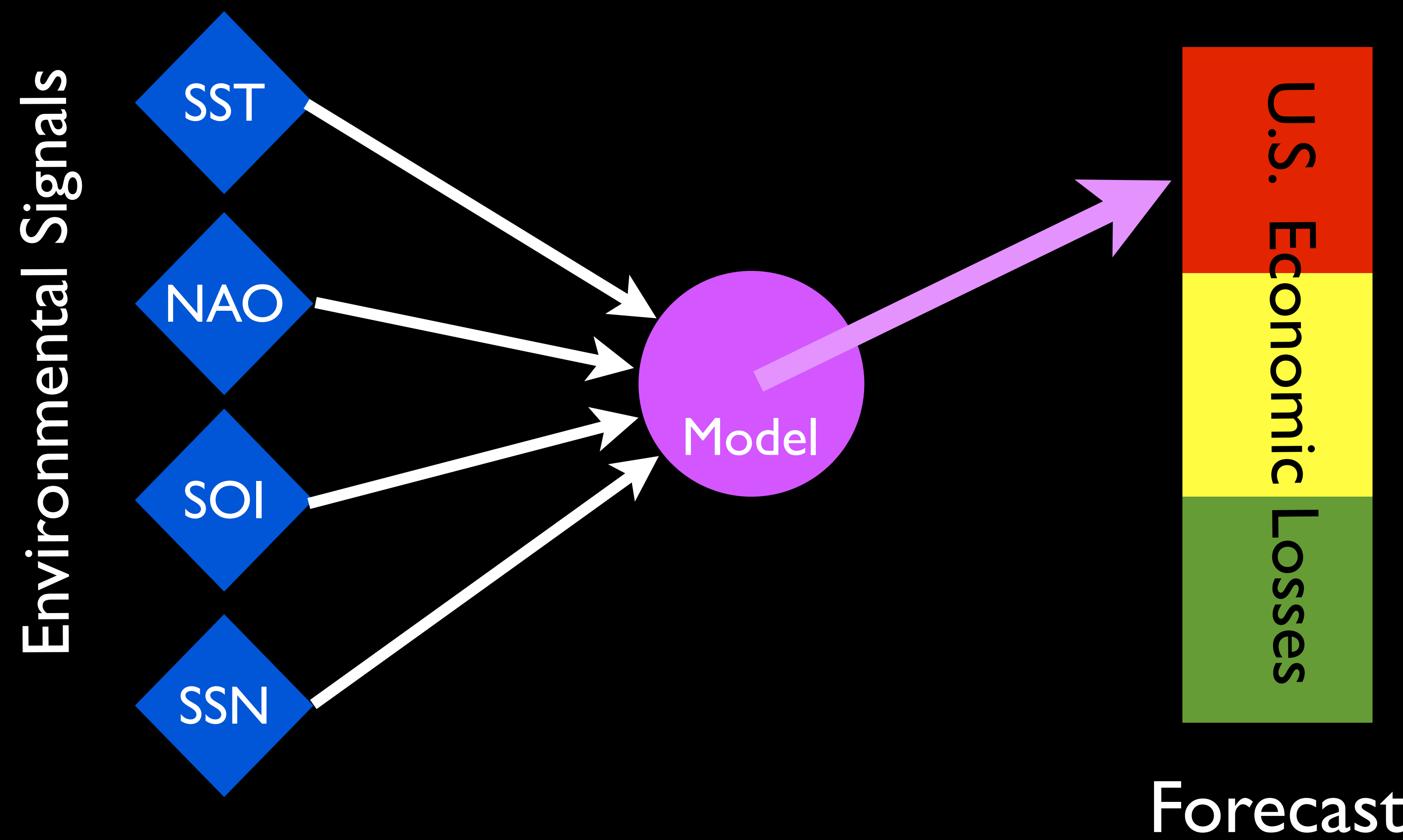




FSU/Climatek

Hurricane Activity Model

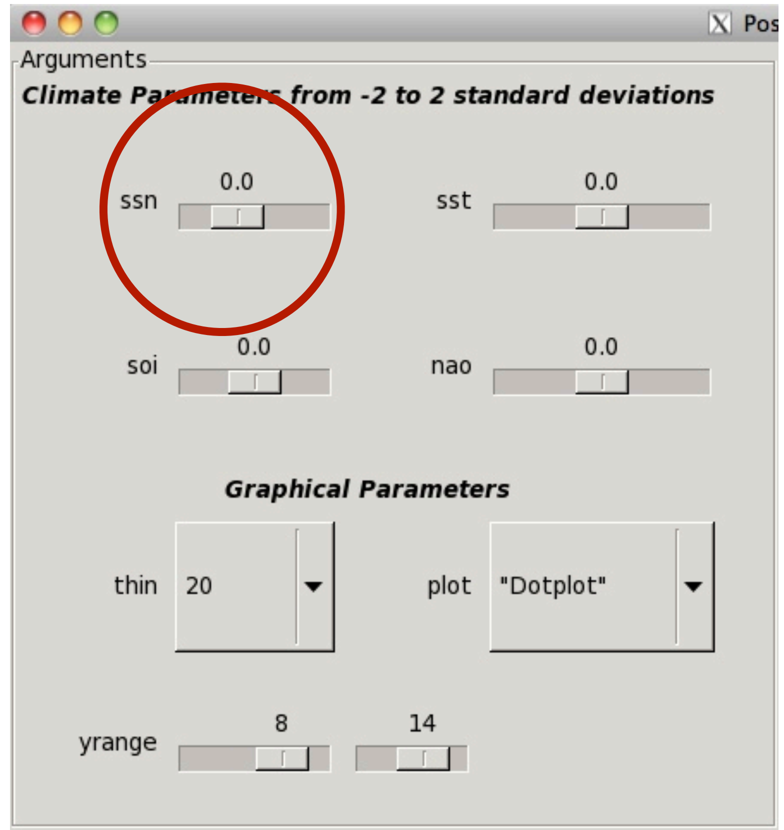
How is it used?



FSU/Climatek

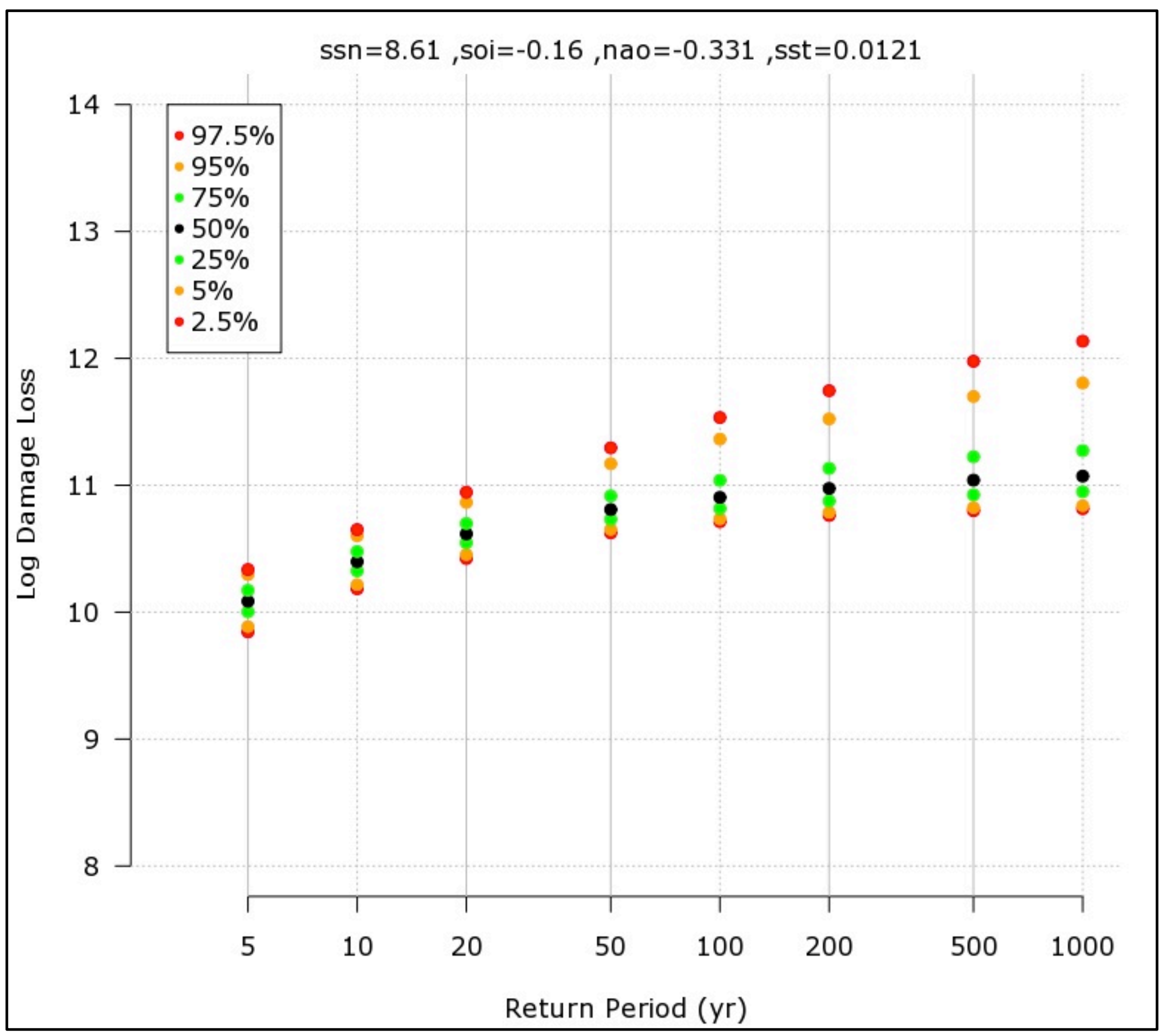
Hurricane Economic Loss Model

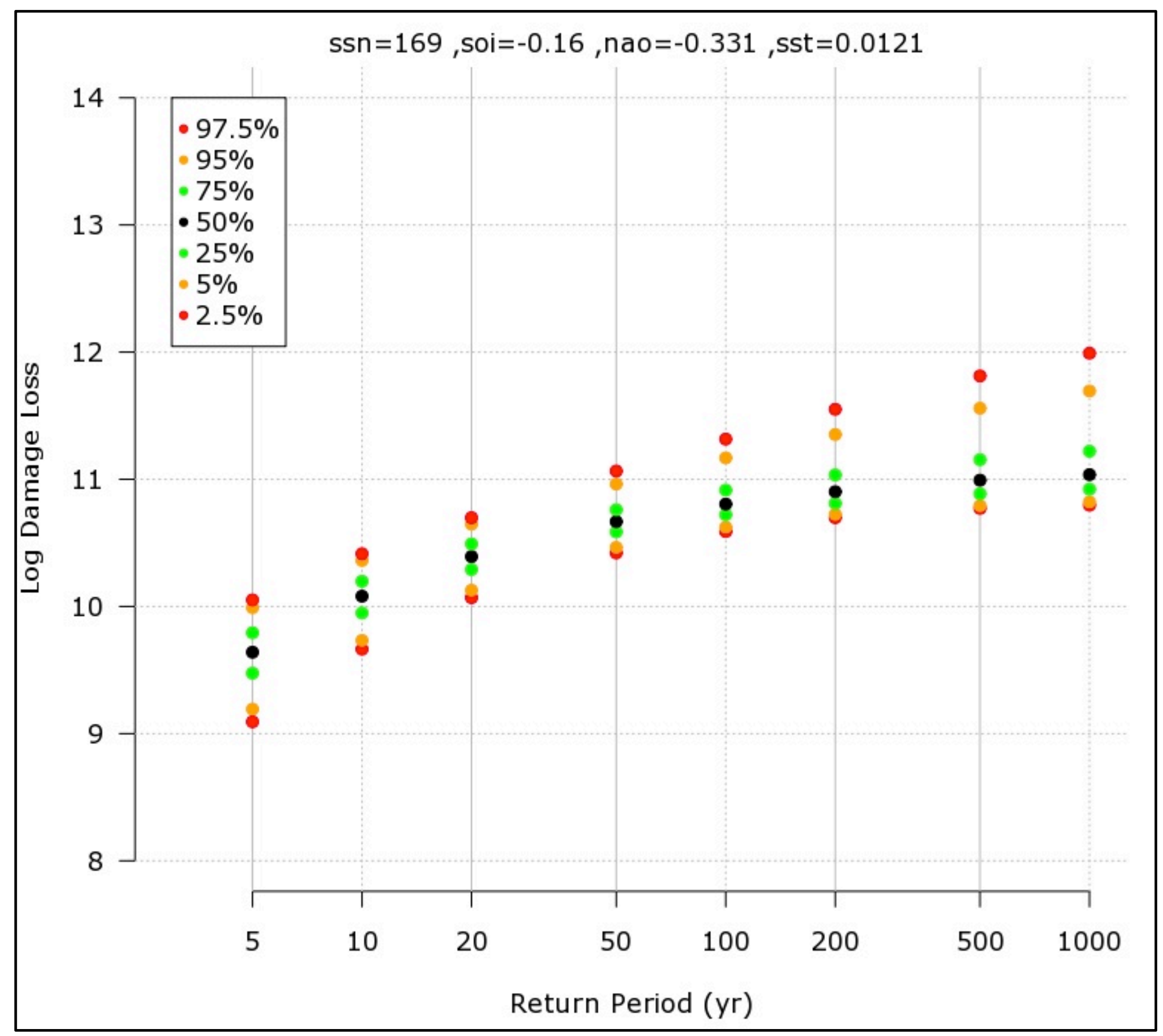
Climatek’s Loss Calculator



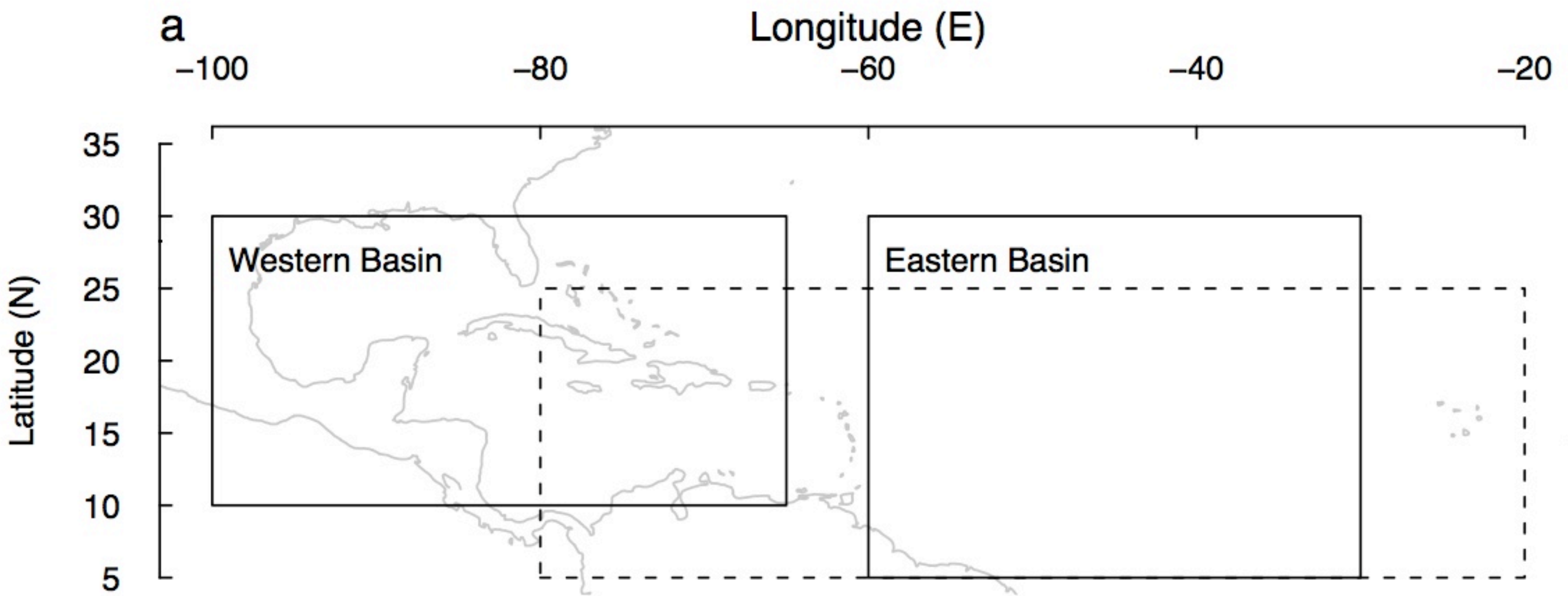
Inactive Sun

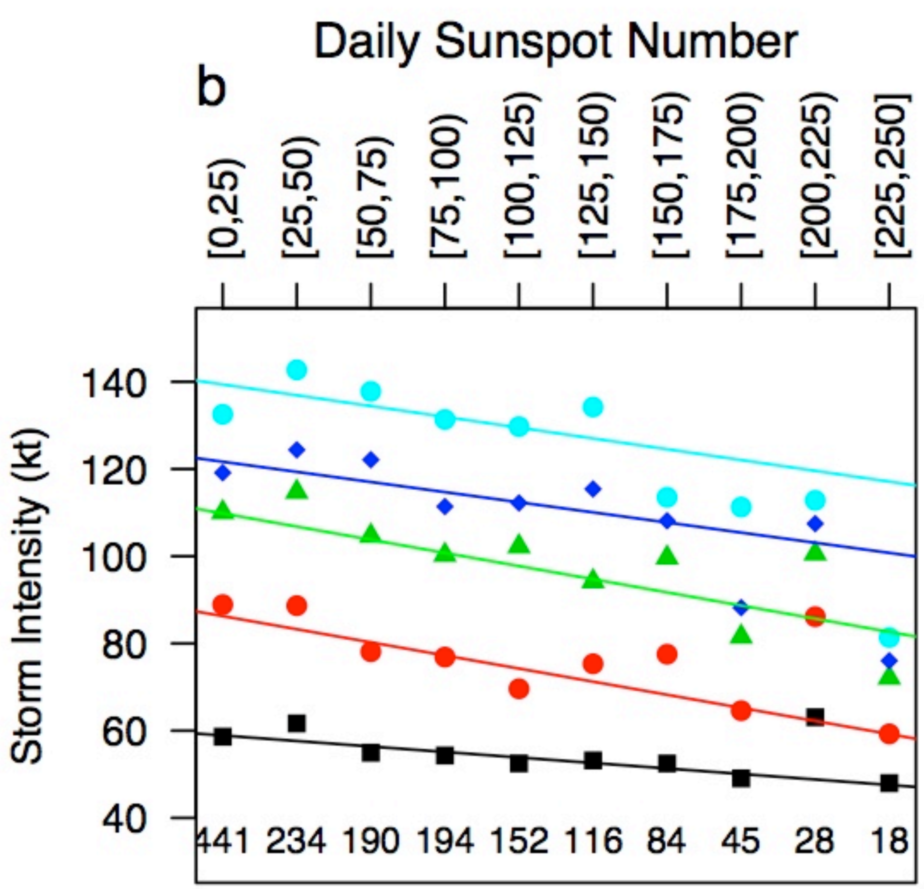
Active Sun





Is the signal apparent in daily data?





Percentiles

Cyan: 99th
Blue: 95th
Green: 90th
Red: 75th
Black: 50th

Quantile	Estimate	S.E.	t value	P value
Q50	−0.025	0.006	−4.017	<0.001
Q75	−0.060	0.012	−4.908	<0.001
Q90	−0.061	0.014	−4.368	<0.001
Q95	−0.046	0.014	−3.461	0.001
Q99	−0.050	0.021	−2.342	0.019

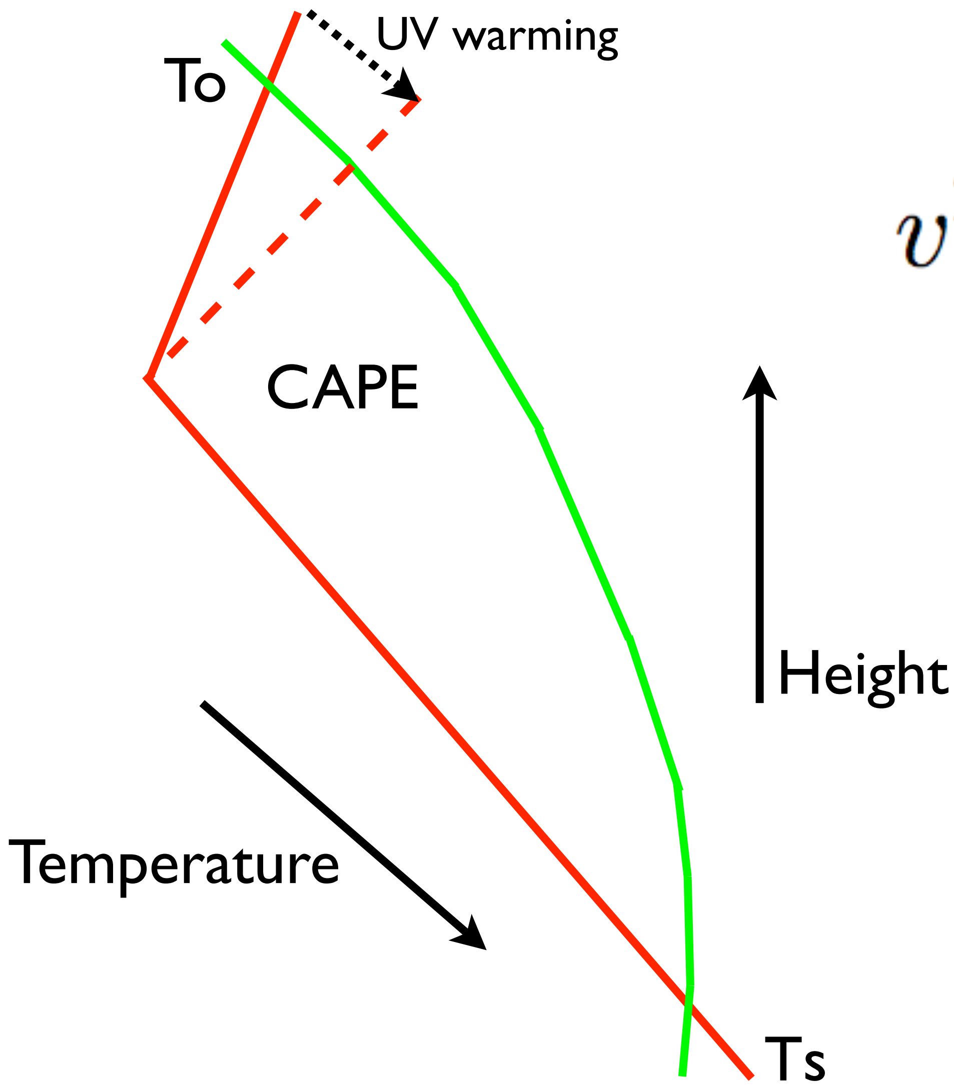
Elsner and Jagger 2008

Is the relationship be due to changes in stratospheric temperature?

Aug-Oct mean air T vs Aug-Oct SSN count. P is the pressure level with lower values indicating higher elevations. Positive correlation (r) indicates cooler air with fewer SSN.

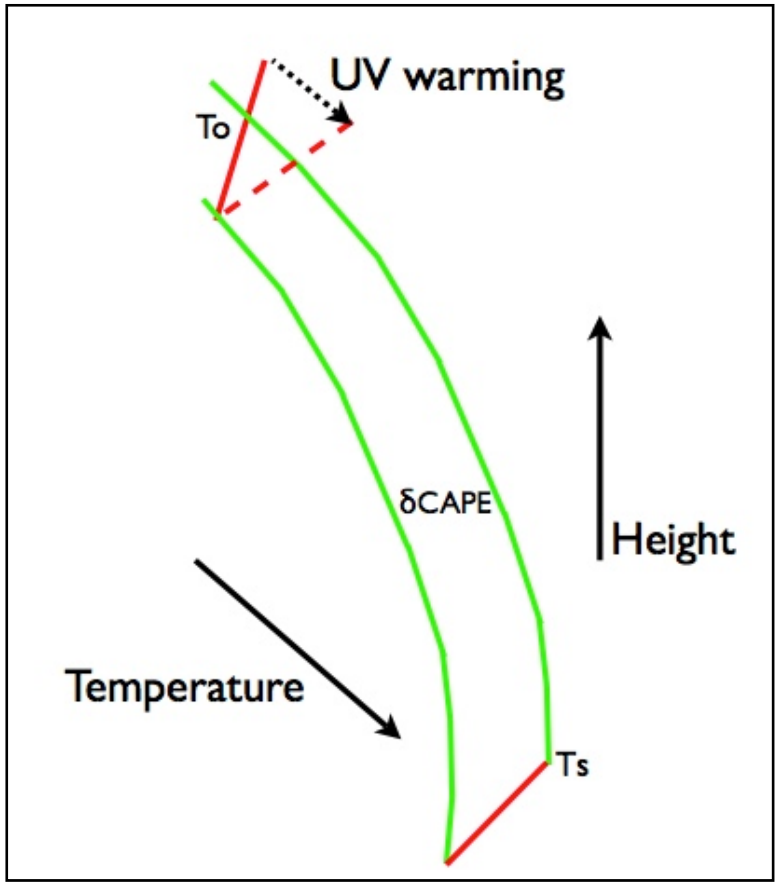
P (hPa)	r(T_{NCAR}, SSN)	*P* value	r(T_{NOAA}, SSN)	*P* value
30	+0.24	0.070	+0.32	0.027
50	+0.23	0.078	+0.18	0.206
70	+0.16	0.212	+0.11	0.459
100	+0.22	0.089	+0.21	0.152
150	+0.21	0.115	+0.32	0.025
200	+0.18	0.164	+0.26	0.075
Avg	+0.29	0.027	+0.28	0.055

How does it work?



$$v^2 = \frac{c_k}{c_D}\frac{T_s}{T_o}[\mathrm{CAPE}_s - \mathrm{CAPE}]$$

K. Emanuel's MPI theory

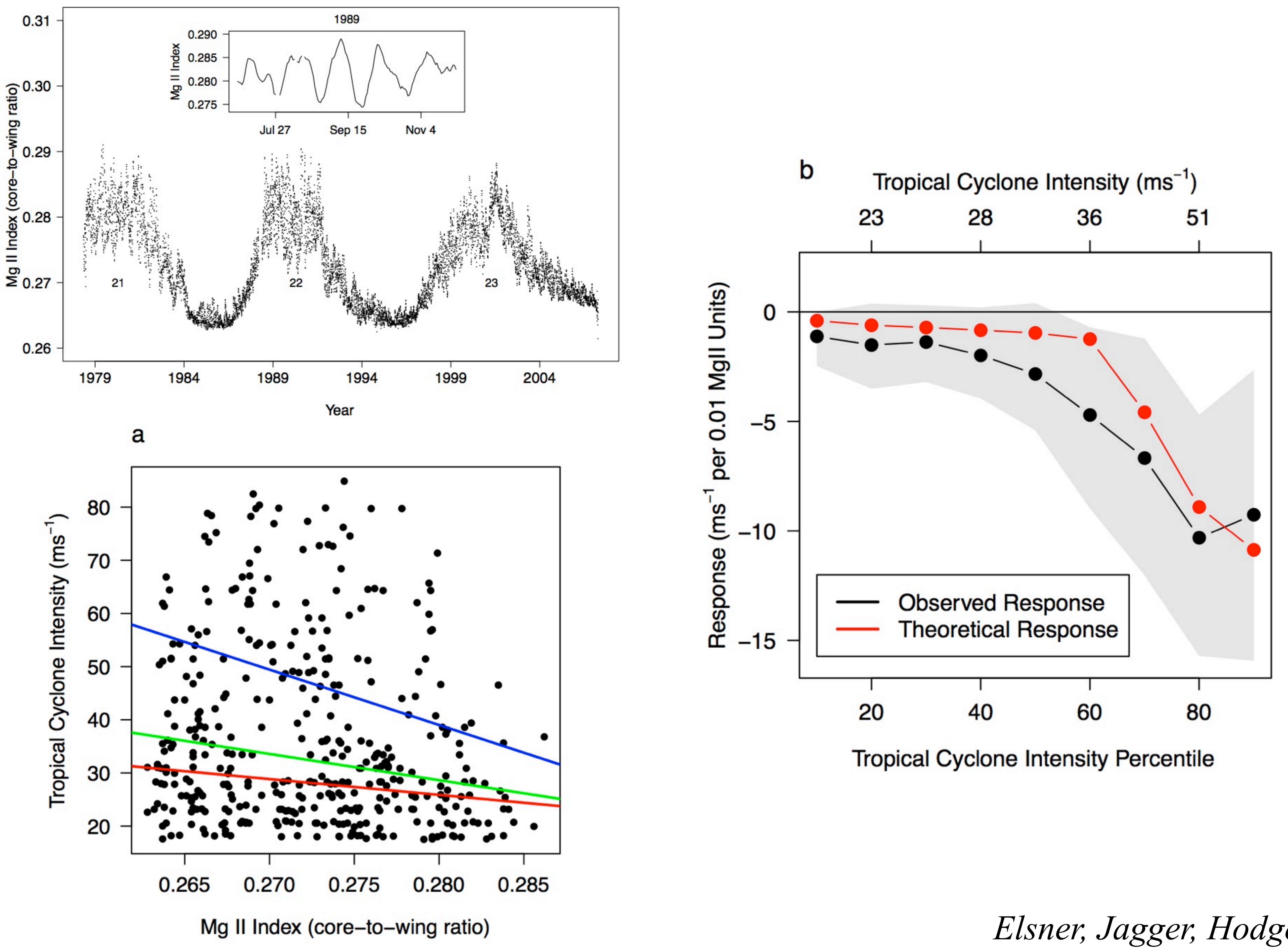


UV warming of ~ 1 K @ 100 hPa

$$\underset{-10\%}{\underline{\Delta v}} = \frac{v}{2}\left[\frac{\cancelto{0}{\Delta T_s}}{T_s} - \underset{+2\%}{\underline{\frac{\Delta T_o}{T_o}}} + \underset{-18\%}{\underline{\frac{\Delta\delta\mathrm{CAPE}}{\delta\mathrm{CAPE}}}}\right]$$

50 m/s hurricane weakens to 45 m/s

How well does the theory match the observations?



Elsner, Jagger, Hodges 2010

Summary

The probability of a U.S. hurricane from year to year fluctuates with sunspot numbers.

The relationship can be used to predict U.S. hurricanes and associated wind damage losses.

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The relationship is consistent with the heat-engine theory of tropical cyclone intensity.

Questions?

More Information?

http://myweb.fsu.edu/jelsner